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Opportunities of GHGs Emission Minimization through Processes Improvement in Iranian Oil Industries

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Abstract

Iran is located in dry and arid region. This country faces to shortage of water resources for drinking and agriculture. Increasing of earth temperature causes direct and negative effects in different economical sectors in Iran. Therefore department of environment (DOE) is established some programs for GHGs emission reduction. According to these programs GHGs emission in Iranian energy sector must be reduced about 30 percent. Now, GHGs emission per GDP (kg equal CO_2 per GDP) index in Iran (3.07 kg CO_2/2000US$) is more than world average (0.73 kg CO_2/2000US$) and Asia average (1.26 kg CO_2/2000US$). Also emission factor of CO_2 in Iranian oil refineries is about 3.5 times more than European ones, like England. Hence, the main goal for GHGs reduction in Iran is achievement to Asia average level. Since, potential of GHGs emission reduction is estimated about 67 million tones equal CO_2 at 2025 in oil sector. The major part of this reduction is related to petrochemical complexes. It should be considered that the most of these industries are old and worn out, so there are several effective techniques for their GHGs emission reductions. Also cost of tone CO_2 reduction in Iranian oil sector is very lower than same industries with new technologies. For this purpose, Naphtha hydrotreating unit of Abadan oil refinery and wastewater treatment plant and waste incineration furnace of Tondgouyan petrochemical complex are selected as case studies. Gained results showed that by process changing in Naphtha hydrotreating unit from once-through system to recycle system, the gas burning will reduce to10.6 million kg per year. Also injection of produced methane (from anaerobic reactors of wastewater treatment plant) to waste incineration furnace, about 1.75 million cubic meter will saved due to prevention of gas sending to flare. All mentioned results reveals that GHGs reduction is possible via detection of energy losses and process problems in all units of refineries and petrochemical complexes. Obviously, expanding of economical relationships with developed countries and application of some mechanisms such as CDM can be very important and effective.

Keywords: GHGs emission reduction; Oil industries; Process improvement; Iran

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1. Introduction

Industrialization caused release of enormous amounts of greenhouse gases into the environment as result of fossil fuel combustion. This has been a major reason for the climate changes predicted for the near future that we already observe now. Most of the rise (0.6°C) in average global temperature measured in the twentieth century can be attributed to human impact on the composition of the atmosphere; a much higher increase (1.4 to 5.8°C) is predicted for the future (1,2,3,4). The increasing trend of GHGs in the world that is mainly due to the use of energy consumption has created many environmental crises including global warming. Increasing in earth temperature has left some adverse environmental impacts such as drought and reduction of agricultural crops in the arid and semi-arid areas in Iran. So, executive programs are necessary for GHG emission reduction in this country (5). The share of Iran in global net production is about 0.5% while 2.1% of global GHGs emission is routed from Iran. The main causes of high GHGs emission is due to application of old technologies in industrial sector, low prices of fuels, high energy losses in production units and burning of by-product gases in flares. Also, oil sector has the main role in GHGs emission in Iran. GHGs emission rate in different part of the world is showed in Figure 1. Total GHGs emission was equal to 28962 million tones CO_2 in the world in 2007(6,7). Also GHGs emission of Iran in 1994 and 2007 were equal to 337.5 and 465.9 million tones CO_2 respectively (Table 1). According to this table, GHGs emission from oil sector is about 36 percent of total GHGs emission in Iran. Low prices of oil and gas and old technologies that used in different sectors such as industries, transportation and agriculture in some countries has lead to inefficient use of energy and such trend of consumption may lead to deterioration of environment (8). The oil and gas sector is the backbone of the Iranian economy. The share of this sector in GDP is currently about over 23% (9). Oil export accounts for nearly 85% of total export earnings in Iran. The oil and gas sector provides for over 60% of governmental budgetary revenue. To maintain the vital share of oil and gas sector to the national economy, large capital investments are required. Main aim of the present study was determination of GHGs emission reduction opportunities in oil and petrochemical industries of Iran. Hence, Abadan oil refinery and Tondgouyan petrochemical complex both in southwest of Iran (Figure 2).

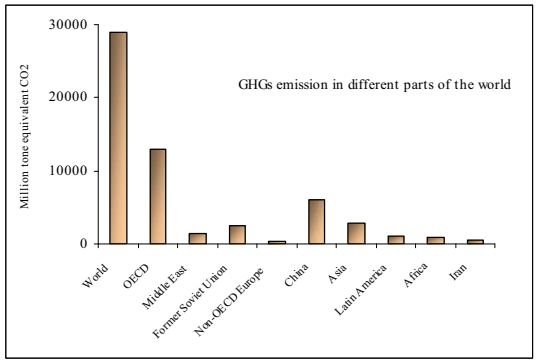


Figure 1. GHGs emission in different parts of the world

Table 1. GHGs emissions in different sectors of Iran

Sector	Emission rate in 1994 (million tones)	Emission rate in 2007 (million tones)
Power plant	51.91	65.22
Oil and gas	70.321	167.72
Industry	72.30	83.86
Transportaion	58.71	60.56
Household/commercial	66.51	74.54
Acriculture	12.69	13.97
Others	5.97	4.65
Total	337.525	465.90

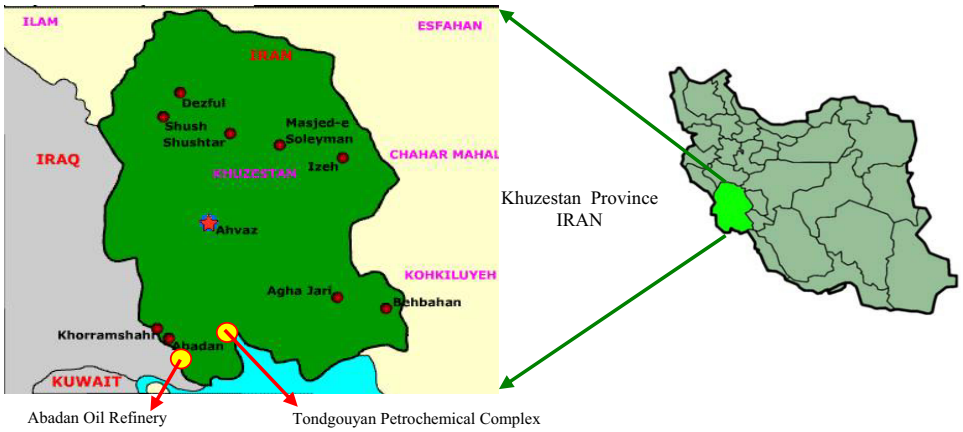


Figure 2. Location of Abadan oil refinery and Tondgouyan petrochemical complex in southwest of Iran

2. Material and methods

2.1. GHGs emission of Iranian oil refineries

There are nine refineries in Iran that refine crude oil and produce other by-products of oil with nominal capacity of about 1,347 bbl/day. Table 2 shows percentile of nominal to operational capacity of oil refining in 2004. All the country's refineries (except for Bandar Abbass refinery) are designed for production of high quality and light crude oil. In the year 2006, about 59.1%, 31.2% and 9.7% of byproducts were attributed to light and semi-condensates, fuel oil and heavy oil respectively. It should be pointed out that present capacity of production of gasoline and fuel jet does not meet country's demand. Oil refineries have considerable share of GHGs emission in Iran. The emission factors of CO_2 and NO_x are 3.5 and 4.2 times higher than British refineries, respectively (5). In order to have a sustainable development in Iranian oil refineries, the government has to set emission factors of European Community as her goal (7). Also Figure 3 illustrates CO_2/GDP index in different parts of the world in 2007. As it is clear, world's average of CO_2/GDP index was equal to 0.73 kg CO_2 as 2000 US$ while CO_2 GDP in Iran is about 3.07 kg CO_2 as 2000 US$ value that should be reduced to Asia average (1.26 kg CO_2/GDP) in the year 2025. According to mentioned scenario, total GHGs emission reduction in Iranian oil industries will be 67.1 million tones CO_2 equivalent. The share of oil refineries in this reduction is about 12.9 million tones CO_2 equivalent. Gas sector, petrochemical industries and upper oil industries contribute to GHGs emission reduction equal to 6.6 million tones CO_2, 7.2 million tones CO_2 and 40.3 million tones CO_2 per year, respectively.

Table 2. Percentile of nominal to operational capacity of oil refining in Iran, 2004

No.	Refinery	Nominal capacity (Thousand barrels)	Share of production (%)
1	Abadan	350	21.07
2	Esfehan	200	22.12
3	Arak	150	11.37
4	Tehean	220	15.28
5	Bandar Abas	232	16.71
6	Tabriz	110	7.08
7	Kermanshah	25	1.37
8	Shiraz	40	3.16
9	Lavan	20	1.84
	Total	1347	100

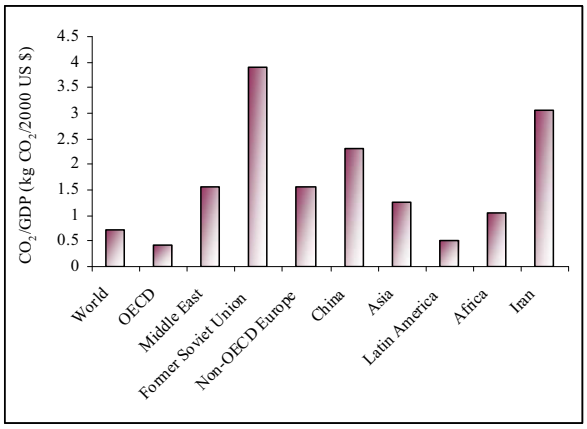


Figure 3. CO_2/GDP index in different part of the world in 2007

To achieve mentioned goals, opportunities of GHGs emission reduction must be identified in studied oil refinery. For this purpose, identification of air pollutants and GHGs emission sources and energy loss points in all units is necessary. Since process improvement will reduce GHGs emission through technical methods. Catalytic reforming unit is one of the oldest units of Abadan refinery. This unit designed and constructed by "Flour Engineering and Construction Company" in 1960 (10). At present the naphtha hydrotreating unit is an once_ through gas system which unreacted gas (gas contains H_2S) routed to the refinery fuel gas system. It releases great amounts of air pollutants such as sulfur oxides and carbon dioxide into the atmosphere (11). Consequently, changing in the process of naphtha hydrotreating unit from once-through gas system to recycle gas system might be minimized the air pollutants emission.

Process improvement of naphtha hydrotreating unit from the once-through gas system to the recycle gas system is carried out through several stages. At first this unit was simulated in current conditions and its results were compared with the real condition in order to determine the differences between the real results and collected results. Then naphtha hydrotreating unit in the recycle gas system was simulated and the findings were written down. Finally the coke-burring operation in the recycle gas system was simulated.

2.2. GHGs emission of petrochemical complexes in Mahshahr petrochemical zone

Mahshahr petrochemical zone includes numerous petrochemical complexes in southwest of Iran, Khuzestan province. Table 3 indicates the list of petrochemical complexes along with their productions. Also GHGs emission rate in some petrochemical complexes are provided in Table 4. As Table 4 reveals total amounts of GHGs emission are considerably high. So, wastewater treatment plant and waste incineration furnace of Tondgouyan petrochemical complex were selected as case studies in Mahshahr petrochemical zone.

In Tondgouyan petrochemical complex, wastewater treatment plant includes three anaerobic reactors that one is designed for PET and two others designates for first and second phases of PTA unit. PET reactor is UACF and can treat 1777 m^3 wastewater with influent value of 6300 (mg/L) COD by 65% efficiency. The PTA reactors are AF type and can treat 7460 m^3 wastewater with influent value of 4800 COD (mg/L), daily. The media of all reactors are made from plastic to increase the contact surface between pollutants and micro organisms. Treatment process consists of three stages including hydrolyze, acidification and methanization. At the end of treatment processes, the produced materials change to more simple compounds mainly CH_4 and CO_2 (12). The produced gases are send to flare for burning that cause GHGs release into the atmosphere, while it can be used in the waste incinerator furnace (that uses natural gas). If the furnace fuel supply changes to produced gas resulting from wastewater treatment plant, air pollution emission rate and application of energy sources will decrease. Generally gas consumption rate in waste incinerator furnace is 1265.82 ton/year. Natural gas specifications that are sending to waste incinerator are provided in Table 5. Also properties and flow rate of produced biogases in waste water treatment plants are determined.

Average amount of produced biogas is about 428 m^3/hr (Table 6). Also results of gas analysis show that minimum amount of methane in biogas is 70% (Figure 4).

Table 3. List of petrochemical complexes in Mahshahr petrochemical zone (13)

Petrochemical complex	Feed	Production	Capacity (tone/year)
Marun	Ethane Ethylene Natural gas Oxygen	Ethylene Propylene Ethylene Oxide and Glycol	1100000 200000 440000
Fanavaran	Natural gas Carbonic gas	Methanol CO Acetic acid	1000000 140000 150000
Khuzestan	Natural gas NaOH CL(Liquid) Acetone Phenol	Phosgene Bisphenol A Poly carbonate	11360000 30000 25000
Tondgayan	Parazaylene Acetic acid Ethylene Glycol	PTA PET-A PET- D, PET- B, PET- C PET- F, PET- G STAPLE, POY	350000 60000 1175000 66000
Bu-Alisina	Kerosene Liquid gas	Xylene Benzene LPG Naphtha Heavy Aromatic Pentane	430000 180000 39000 838000 23000 21000
Karun	-	TDI MDI	40000 40000
Amir kabir	Butane LPG	Ethylene Propylene Butane 1-3 Butadiene CFO	No data
Razi	Natural gas Phosphate soil	NH3 H2SO4 Sulfur Deammonium phosphate Ammonium sulfate	No data
Farabi	-	PA DOP	No data
Bandar-e-Emam	LPG Fuel gas Salt Naphtha Water Xylene	Ethane Propane Butane Pentane Heavy Aromatics Kerosene MTBE	No data
Fajr		Utility	

Table 4. GHGs emission rate from some petrochemical complexes in Mahshahr petrochemical zone

No.	Petrochemical complex	GHGs emission as CO_2 (M tone/year)	Share of emission (%)
1	Khuzestan	192.4×10^{-6}	0.0021
2	Amir Kabir	0.813	8.83
3	Bu-Alisina	6.381	69.37
4	Fajr	0.973	10.57
5	Tondgouyan	1.037	11.26
	Total	9.2042	100

Table 5. Results of natural gas analysis

Gas	CH_4	C_2H_3	C_4H_8	C_4H_{10}	C_5H_{12}	N_2	Total acidic gases
Percentage	0.83.23	10.97	3.41	1.24	0.25	0.54	0.36

Table 6. Flow rate of produced biogas in anaerobic reactors

Sampling period	June (m^3/hr)		July (m^3/hr)		August (m^3/hr)	
	PET		PTA		PET	
First of the mount	144	347	105	419	63	215
Middle of the mount	132	331	83	355	90	194
End of the mount	123	332	155	501	42	221
Average	133	337	114	425	66	*210*

3. Results:

Figure 5 compares the analysis of the output gas from Naphtha hydrotreating unit of Abadan oil refinery in current operational condition (once through gas system) and the recycle gas system. This Table also specifies the amount of the hydrogen-rich gas in the current once- through gas operational condition and the amount of the necessary hydrogen-rich gas in the recycle gas system. The advantage of recycle gas system is that the main part of produced gas returns to the process. It causes prevention of gas burning in the flare.

Results of CO_2 and SO_2 emissions in both before and after process improvement are tabulated in Table 7. As it is clear process improvement reduces CO_2 emissions about1803 kg/day and SO_2 levels more than twice.

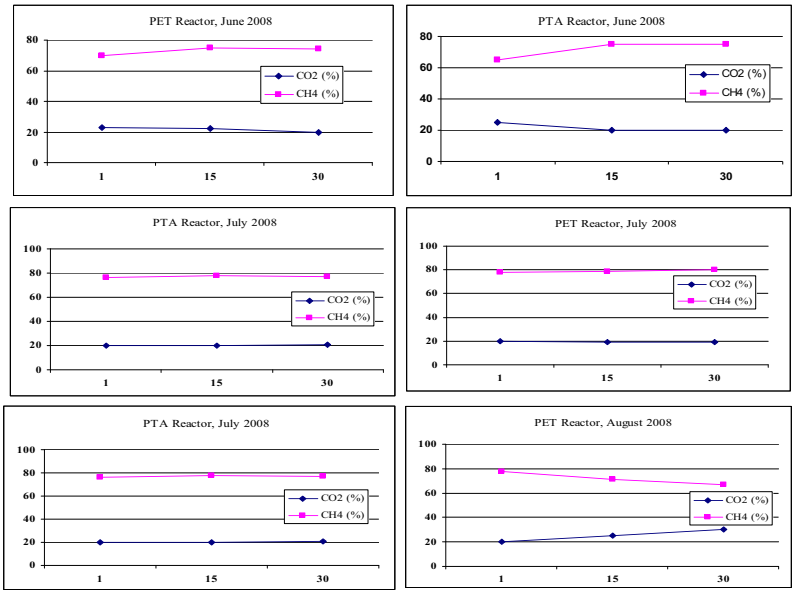
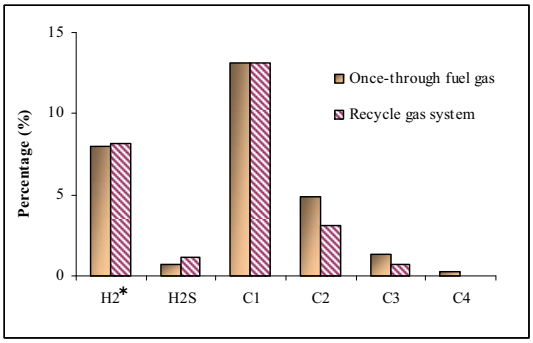


Figure 4. Analysis results of produced biogas in PET and PTA reactors of Tondgouyan petrochemical complex wastewater plant



*H_2 percentage × 10

Sending gas flow rate to fuel gas system in Once-through process= 38936 (kg/day)

Sending gas flow rate to fuel gas system in Recycle gas process= 9649 (kg/day

Figure 5. Comparison of specifications of output gas to flare from once-gas and recycle gas process in naphtha hydrotreating unit

Table 7. Results of CO_2 and SO_2 emissions into the atmosphere from combustion of hydrogen rich gas in refinery fuel gas system

Parameter	Once-through process	Recycle gas process	Reduction amounts
CO_2 (kg/day)	2129.1	326.1	1803
SO_2 (kg/day)	272.5	136	136.5

Also through the once–through coke-burning operation a considerable amount of CO_2 (1654 Kg CO_2 during each regeneration) and SO_2 (up to 20 pmmv concentration in reactor exhaust) are released. Via improvement the process from the once –through gas system to the recycle gas system, CO_2 emission as a greenhouse gas reduces to 1654 kg/day during each regeneration. Moreover this revision leads to the elimination of SO_2 emission from system.

Results of improvement process in studied petrochemical show that the heat values of produced biogas 70% and 75% methane in wastewater treatment of Tondgouyan petrochemical complex are 21931.23 kj/kg and 29960 kj/kg respectively. The coefficient exchanger of methane 70% and 75% to natural gas will be 2.25 and 1.65 respectively, due to natural gas heat value (49450 kj/kg).

The furnace incinerator needs to about 200 kg/hr of gas by regarding to the highest rate of entrance fuel to waste incinerator. Hence the different stages of substituting natural gas by 70% and 75% of methane is providing in Table 8. According to Table 8 if the minimum natural gas (17.8 kg/hr) is required for furnace, injection of 250.6 kg/hr and 188.1 kg/hr methane 70% and 75% are needed respectively as natural gas substitution.

Gained results reveal that anaerobic reactors can produce 500 to 600 m3/hr biogas in different conditions. So the average production of methane is about 283 kg/hr according to its mass percentage (46%) in biogas. Therefore through replacement of natural gas by produced methane, it could prevent burning of 2483 tone methane in Petrochemical flare, each year. Since, reduction amount of CO_2 emission will be about 45315 tones CO_2, yearly. If the produced biogas be used only in furnace of waste incinerator, economical benefit will reach to 32000 US$ per year, according to national price of natural gas. Based on implementation of studied pilot investment expenses, the restoration time of investment will be 28 months.

Table 8. Different stages of substituting natural gas by 70% and 75% of methane

Step	Use of natural gas		Use of biogas with 70% Methane		Use of biogas with 75% Methane	
	Kg/hr	m^3/hr	Kg/hr	m^3/hr	Kg/hr	m^3/hr
1	200	112	0.0	0.0	0.0	0.0
2	178	100	29.5	27	22.1	19.8
3	160.2	90	54	49.5	40.6	36.3
4	142.4	80	78.6	72	59.1	52.8
5	124.6	70	103.2	94.5	77.6	69.3
6	106.8	60	127.8	117	46.1	85.8
7	89	50	152.3	139.5	114.2	102.3
8	71.2	40	176.9	162	133	118.8
9	53.4	30	201.5	184.4	151.5	135.3
10	17.8	10	250.6	229.5	188.1	168.3

4. Conclusion

Index of CO_2/GDP as 2000 US$ in Iran is more than world and Asia average. Air pollutants and GHGs emission factors are higher in Iranian oil refineries in comparison with same industries by new technologies. So oil and gas sector has the most shares in GHGs emission in Iran. Since, targets of Iranian strategy plans should be movement towards a low carbon future in oil and gas sector. According to this target, reduction of GHGs emission must be aimed to about 67 million tones till the year 2025. Gained results reveals that optimization of energy consumption is applicable in all units of oil refineries and petrochemical complexes. Also emission reductions are considerable and economical due to controlling actions and process improvement. Moreover, the price of tone carbon reduction is estimated about one US$ in the studied units, therefore the investment on GHGs emission reduction plans (as CDM projects) will be very economical and attractive. Generally, it should be considered that the main parts of Iranian oil industries are old and worn out so the potential GHGs emission reductions are very high for them. Also beside of

process improvement plans, identification and enhancement of carbon capture sources are very important in the country.

5. Acknowledgement

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